4.7 External Radiation Surveillance

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External radiation is defined as radiation originating from a source external to the body. External radiation fields consist of a natural component and an anthropogenic, or man-made, component. The natural component can be divided into 1) cosmic radiation; 2) primordial radionuclides, primarily potassium-40, thorium-232, and uranium-238; and 3) an airborne component, primarily radon and its progeny. The man-made component consists of radionuclides generated for or from nuclear medicine, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (National Council on Radiation Protection and Measurements 1987).

The interaction of radiation with matter results in energy being deposited in that matter. This is why your hand feels warm when exposed to a light source (e.g., sunlight, flame). Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement, called the rad, was introduced for this concept in the early 1950s. The International System of Units introduced the gray and is defined as follows: 1 gray is equivalent to 100 rad (American Society for Testing and Materials 1993). For a point of reference, a radiological dose of 100,000 mrem beta/gamma to an 8-ounce cup of water will deposit enough energy in the water to increase the temperature of the water by about 1° Fahrenheit.

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter that absorbs and stores energy of ionizing radiation within the dosimeter's crystal lattice. By heating the material under controlled laboratory conditions, the stored energy is released in the form of light, which is measured and related to the amount of ionizing radiation energy stored in the material. Thermoluminescence, or light output exhibited by dosimeters, is proportional to the energy absorbed, which by convention is related to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (Shleien 1992). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1, for beta and gamma radiation and the product of all other modifying factors (N). N is assumed to be unity to obtain dose equivalence (H) measured in rem. The sievert is the equivalent of the rem.

$$D \text{ (rad)} = X \text{ (R)} * 1.0$$

$$H \text{ (rem)} = D * N * Q$$

In 1999, environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters and pressurized ionization chambers. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

4.7.1 External Radiation Measurements

In 1995, the Harshaw 8800-series system replaced the former Hanford Standard environmental dosimeter system. The Harshaw environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips and also provides both shallow and deep dose measurement capabilities. Thermoluminescent dosimeters are positioned ~1 meter (3 feet) above the ground at 28 onsite locations (Figure 4.7.1). Figure 4.7.2 shows the locations around the site perimeter, in nearby communities, and distant locations. Figure 4.7.3 gives the locations along the Columbia River shoreline. All thermoluminescent dosimeters are collected and read quarterly. The two TLD-700 chips at each location are used to determine the average total environmental dose at that location. The average dose rate is computed by dividing the average total environmental dose by the length of time the dosimeter was in the field. Quarterly dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the quarterly dose rates and multiplying by 365 days per year. The two TLD-200 chips are included only to determine doses in the event of a radiological emergency.

To determine the maximum dose rate for each distance classification, the annual dose rates, calculated above, for each location were compared and the highest value was reported. The uncertainties associated with the maximum dose rates were calculated as two standard deviations of the quarterly dose rates then corrected to an annual rate.

All community and most of the onsite and perimeter thermoluminescent dosimeter locations are collocated with air monitoring stations. The onsite and perimeter locations were selected based on determinations of the highest potentials for public exposures (i.e., access areas, downwind population centers) from past and current Hanford Site operations. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

The shoreline of the Columbia River in the Hanford Reach is monitored by a series of 24 thermoluminescent dosimeters located in the area from upstream of the B Reactor shoreline to downstream of Bateman Island at the mouth of the Yakima River. Ground contamination surveys are also conducted quarterly at 13 shoreline locations. These measurements are made to estimate radiation exposure levels attributed to sources on the Hanford Site, to estimate background levels along the shoreline, and to help assess exposures to onsite personnel and offsite populations. Ground contamination surveys are conducted using Geiger-Müeller meters (Geiger counters) and Bicron® Microrem meters. Results are reported in counts per minute and microrem per hour, respectively. Geiger counter measurements are made within 2.54 centimeters (1 inch) of the ground and cover a 1-square meter (10-square feet) area. The Bicron® measurements are taken 1 meter (3 feet) above the ground surface and at least 10 meters (33 feet) away from devices or structures, which may contribute to the ambient radiation levels.

Pressurized ionization chambers are situated at four community-operated monitoring stations (see Section 7.4, "Community-Operated Environmental Surveillance Program"). These instruments provide a means of measuring ambient exposure rates near and downwind of the site and at locations distant and upwind of the site. Real-time exposure rate data are displayed at each station to provide information to the public and to serve as an educational tool for the teachers who manage the stations.

4.7.1.1 External Radiation Results

Thermoluminescent dosimeter readings have been converted to annual dose equivalent rates by the process described above. Table 4.7.1 shows the maximum and mean dose rates for perimeter and offsite locations measured in 1999 and the previous 5 years. External dose rates reported in Tables 4.7.1

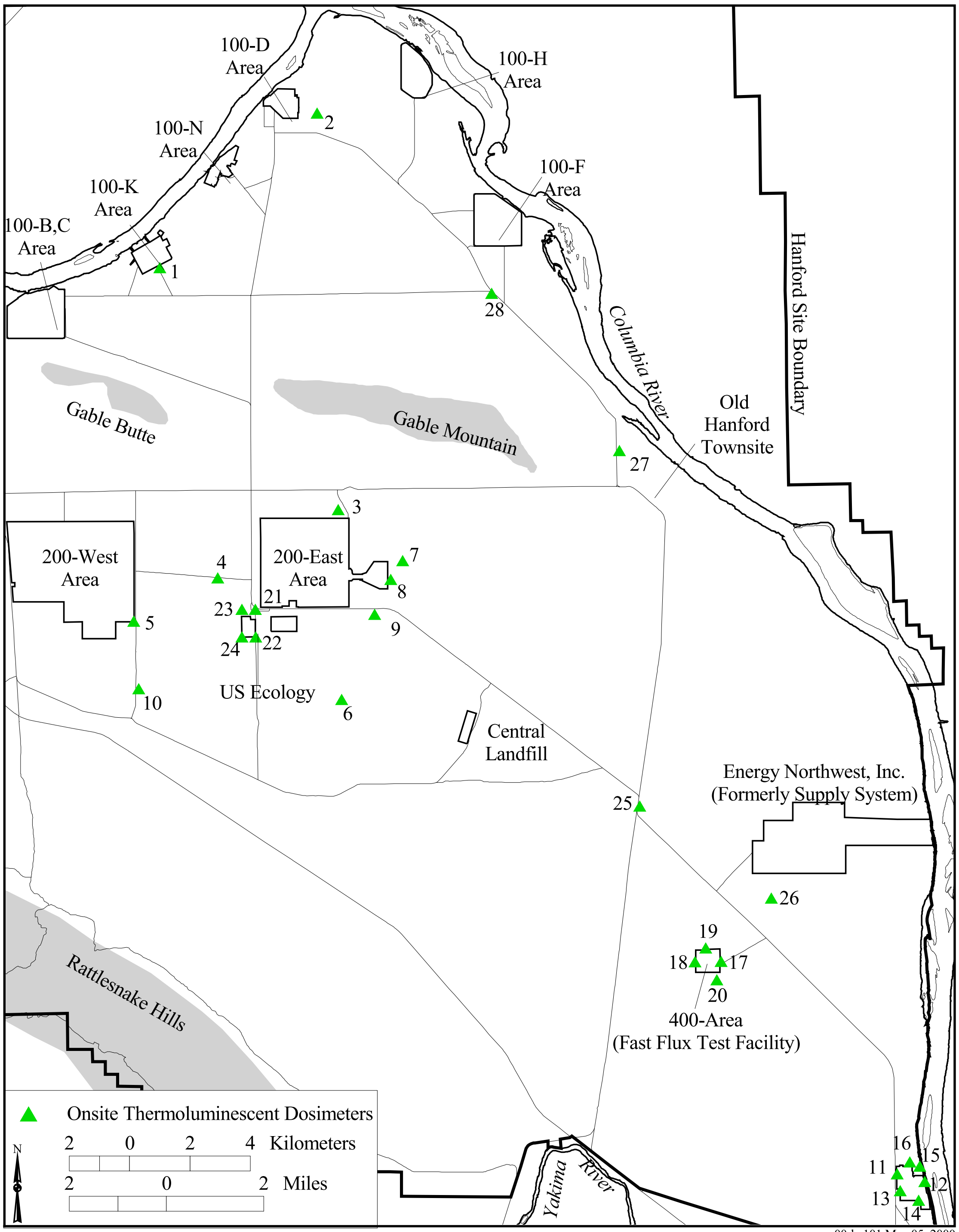

Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1999

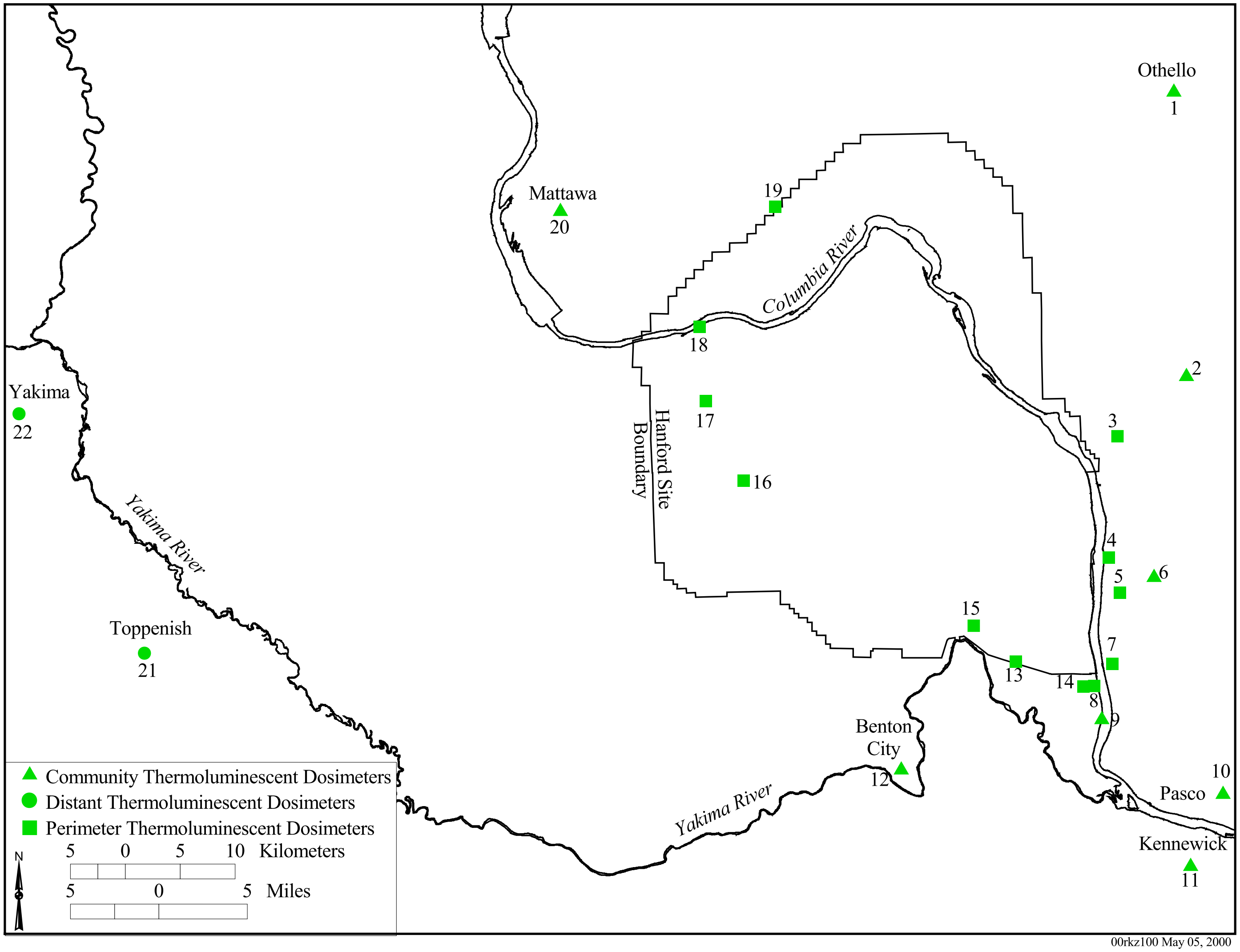

Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1999

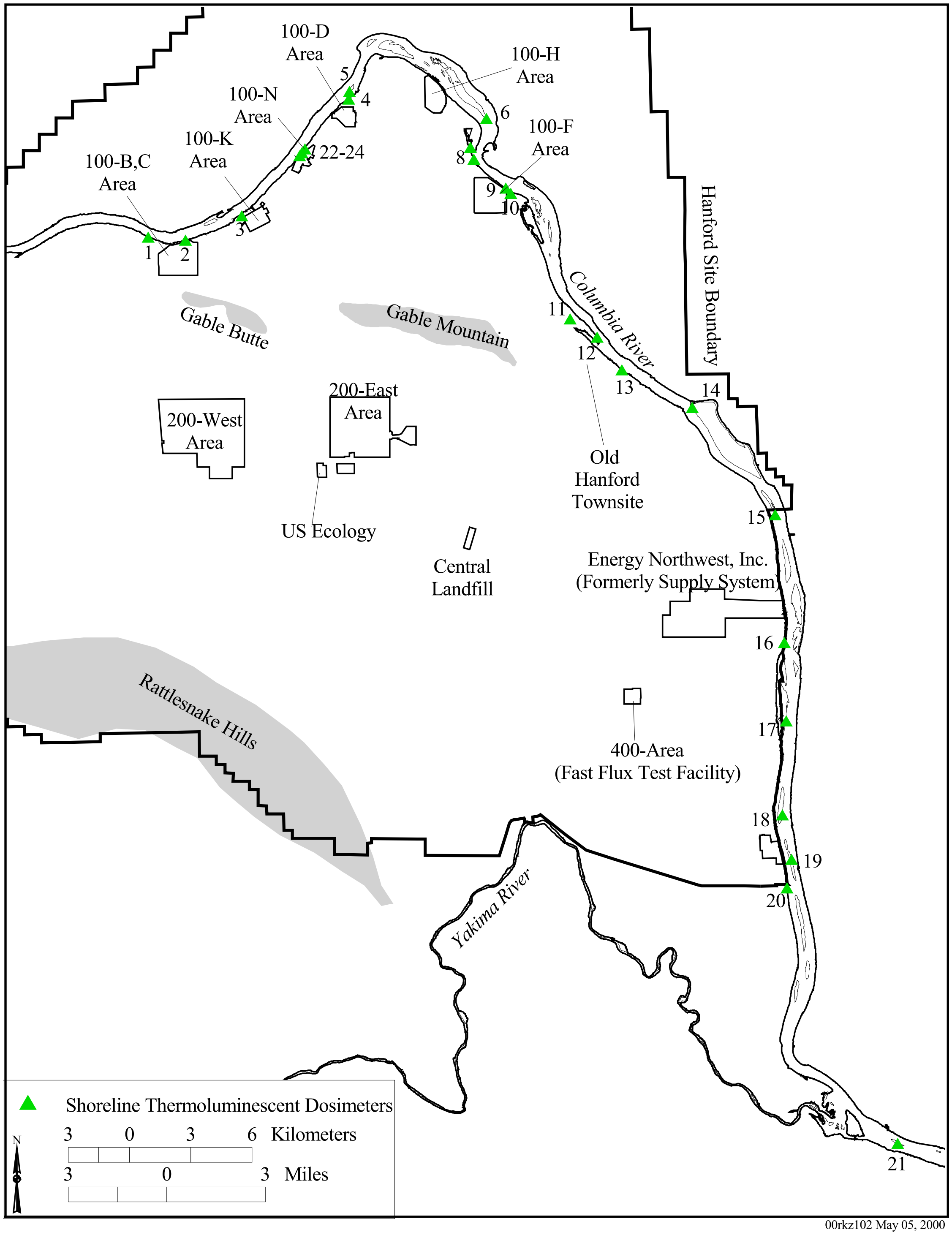

Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers Along the Columbia River, 1999

Table 4.7.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1999 Compared to Previous 5 Years

		1999		1994-1998		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 12	98 ± 8	90 ± 4	27	121 ± 17	92 ± 5
Community	13 - 20	89 ± 2	79 ± 4	32	90 ± 4	78 ± 2
Distant	21 - 22	75 ± 5	74 ± 2	11	100 ± 11	75 ± 6

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.7.2.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging annual means for each location within each distance classification.

through 4.7.3 include the maximum annual dose rate (±2 standard deviations) for all locations within a given surveillance zone and the mean dose rate (±2 standard error of the mean) for each distance class. Locations were classified (or grouped) based on their proximity to the site.

The annual dose rates measured in 1999 are given in Table 4.7.1. The mean perimeter dose rate was 90 ± 4 mrem/yr; in 1999, the maximum was 98 ± 8 mrem/yr and the 5-year perimeter mean dose rate was 92 ± 5 mrem/yr. The mean background dose rate (measured at distant communities) in 1999, was 74 ± 2 mrem/yr, compared to the previous year's mean of 71 ± 1 mrem/yr and the current 5-year average of 75 ± 6 mrem/yr. The variation in dose rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25%) (National Council on Radiation Protection and Measurements 1987). Other factors possibly affecting the annual dose rates reported here have been described in PNL-7124 and include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, and changes in station locations, to name a few. Figure 4.7.4 displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1994 through 1999.

Table 4.7.2 provides the measured dose rates for thermoluminescent dosimeters positioned along the Columbia River shoreline. Dose rates were highest along the shoreline near the 100-N Area and were ~1.4 times the typical shoreline dose rates. The higher dose rates measured along the 100-N Area shoreline have been attributed to past waste management practices in that area (PNL-3127). The 1999 maximum annual shoreline dose rate was 143 ± 5 mrem/yr, which is not significantly different from the maximum of 152 ± 2 mrem/yr measured in 1998, but is significantly different than the 5-year maximum of 246 ± 20 mrem/yr. The 5-year maximum was measured in 1994 along the 100-N shoreline. The general public does not have legal access to the 100-N Area shoreline but does have access to the adjacent Columbia River. The dose implications associated with this access are discussed in Section 5.0, "Potential Radiological Doses from 1999 Hanford Operations."

Table 4.7.3 summarizes the results of 1999 onsite measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at distant locations. The highest average dose rate on

Table 4.7.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 1999 Compared to Previous 5 Years

		1999		1994-1998		
Location	Map Location[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
Typical shoreline	1 - 21	104 ± 34	87 ± 3	117	141 ± 25	92 ± 3
100-N shoreline	22 - 24	143 ± 5	120 ± 26	19	246 ± 20	152 ± 19
All shoreline	1 - 24	143 ± 5	91 ± 6	136	246 ± 20	100 ± 5

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.7.3.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging annual means for each location within each distance classification.

Table 4.7.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 1999 Compared to Previous 5 Years

		1999		1994-1998		
Location	Map Location[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
100 Areas	1 - 2	88 ± 2	82 ± 10	10	108 ± 11	84 ± 8
200 Areas	3 - 11	98 ± 3	90 ± 4	36	121 ± 10	92 ± 4
300 Area	12 - 17	89 ± 4	85 ± 2	30	110 ± 17	86 ± 4
400 Area	18 - 21	89 ± 4	85 ± 3	20	111 ± 18	87 ± 4
600 Area	22 - 28	128 ± 11	93 ± 12	28	165 ± 16	99 ± 8
Combined onsite	1 - 28	128 ± 11	88 ± 3	124	165 ± 16	91 ± 3

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.7.1.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging annual means for each location within each distance classification.

the site (128 ± 11 mrem/yr) was seen in the 600 Area and was due to waste disposal activities at US Ecology, Inc., a non-DOE facility. The 5-year maximum onsite dose rate (165 ± 16 mrem/yr) was also measured in the 600 Area, also at the US Ecology facility.

4.7.2 Radiological Survey Results

In 1999, Geiger counters and Bicron® Microrem meters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provide a coarse screening for elevated radiation fields. The surveys showed that radiation levels at the selected locations were comparable to levels

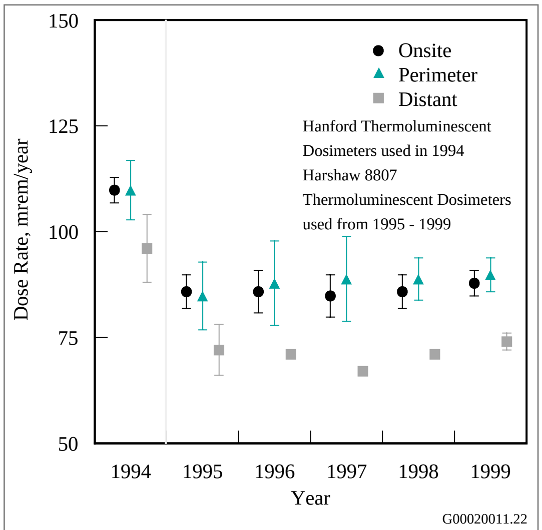

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1994 Through 1999

observed at the same locations in previous years. The highest dose rate measured with the Bicron® Microrem meter (20 μrem/h) was measured in winter along the 100-N Area shoreline; the lowest dose rate measured was 4 μrem/h and was recorded at other locations in the spring and autumn. The highest reported count rate measured with the Geiger counter in ground level surveys was 100 cpm. The lowest ground level count rate (less than 50 cpm) was recorded at the same location and on the same day that the lowest Bicron® reading was recorded.

Survey data are not included in the 1998 surveillance data (PNNL-13230, APP. 1) but are maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be obtained on written request.

Gamma radiation levels in air were continuously monitored in 1999 at four community-operated air monitoring stations (Section 7.4, "Community-Operated Environmental Surveillance Program"). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at Heritage College in Toppenish (see Figure 4.1.1) Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display real-time exposure rate information to the public living near the station, and to be an educational aid for the teachers who manage the stations.

Measurements at the Basin City and Edwin Markham Schools were obtained using Reuter-Stokes Model S 1001-EM19 pressurized ionization chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Systems. Data were collected every 5 seconds; an average reading was calculated and recorded on an electronic data card every 30 seconds. Data cards were exchanged monthly. Readings at the Leslie Groves Park and Heritage College stations were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber, and an average reading was recorded every hour by a flat panel computer system located at the station. Data were obtained monthly from the computer via modem. Data were not collected at every station every month because of problems with the instrument batteries and electrical power. The data collected at each station each month are summarized in Table 4.7.4.

The measurements recorded at Basin City, Edwin Markham, and Leslie Groves Park during the year were similar and at background levels. The readings at Heritage College were also within normal levels, but were, on average, slightly lower than those measured near the Hanford Site.

Generally, monthly exposure rates ranged from a maximum of 33.5 μR/h at Edwin Markham in April to a minimum of 4.8 μR/h at Leslie Groves Park in December (see Table 4.7.4). Median readings at the stations near Hanford were consistently between 8.0 and 8.8 μR/h, and readings at the distant station (Heritage College) ranged between 7.8 and 8.1 μR/h. These dose rates were consistent with those measured by thermoluminescent dosimeters at these locations (Table 4.7.5).

Table 4.7.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Four Offsite Locations[a], 1999

Month		Exposure Rate, μR/h (number of readings)[b]							
		Leslie Groves Park[c]		Basin City[d]		Edwin Markham[d]		Toppenish[c]	
January	Median	8.4	(744)	8.2	(1,406)	ND[e]		7.9	(744)
	Maximum	9.5		9.4		ND		9.3	
	Minimum	5.1		7.9		ND		7.6	
February	Median	8.4	(672)	8.2	(1,392)	8.7	(1,235)	7.8	(675)
	Maximum	8.9		9.1		9.8		8.5	
	Minimum	5.4		7.9		8.3		7.4	
March	Median	8.5	(744)	8.3	(1,466)	8.8	(810)	7.9	(745)
	Maximum	8.9		9.6		9.4		9.1	
	Minimum	6.3		8.0		8.5		7.5	
April	Median	8.4	(720)	8.2	(1,430)	8.7	(918)	7.9	(721)
	Maximum	8.9		8.7		33.5		8.6	
	Minimum	5.2		7.8		8.0		7.5	
May	Median	8.2	(744)	8.0	(1,612)	ND		7.8	(645)
	Maximum	8.9		10.0		ND		8.7	
	Minimum	5.2		7.8		ND		7.5	
June	Median	8.2	(720)	8.0	(457)	ND		7.8	(719)
	Maximum	8.7		8.6		ND		8.6	
	Minimum	7.1		7.8		ND		7.6	
July	Median	8.2	(744)	8.1	(1,605)	ND		7.8	(744)
	Maximum	9.2		8.8		ND		10.6	
	Minimum	6.8		7.8		ND		7.5	
August	Median	8.2	(739)	8.1	(1,340)	ND		7.8	(600)
	Maximum	9.9		10.6		ND		8.5	
	Minimum	5.5		7.6		ND		7.5	
September	Median	8.3	(720)	8.1	(784)	ND		7.9	(721)
	Maximum	9.0		8.6		ND		9.5	
	Minimum	7.8		7.7		ND		7.6	
October	Median	8.3	(744)	8.0	(244)	ND		8.1	(744)
	Maximum	9.5		8.7		ND		9.7	
	Minimum	5.2		7.7		ND		7.6	
November	Median	8.4	(720)	ND		8.7	(1,718)	8.0	(720)
	Maximum	9.2		ND		9.8		9.0	
	Minimum	5.0		ND		8.2		7.5	
December	Median	8.4	(744)	ND		ND		7.9	(671)
	Maximum	9.4		ND		ND		8.7	
	Minimum	4.8		ND		ND		7.6	

(a) Sampling locations are illustrated in Figure 4.1.1.
(b) Number of 30- or 60-minute averages used to compute monthly average.
(c) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(d) Readings are stored every 30 minutes. Each 30-minute reading is an average of 360 individual measurements.
(e) ND = No data collected; instrument or power problems.

Table 4.7.5. Quarterly Average Exposure Rates (μR/h[a]) Measured by Thermoluminescent Dosimeters at Four Offsite Locations,[b] 1999

Quarter Ending	Leslie Groves Park	Basin City	Edwin Markham	Toppenish
March	8.21 ± 0.17	8.29 ± 0.04	8.79 ± 0.21	8.21 ± 0.46
June	8.17 ± 0.13	9.13 ± 0.08	NS[c]	8.92 ± 0.29
September	7.92 ± 0.21	8.88 ± 0.08	8.63 ± 0.04	8.08 ± 0.21
December	8.29 ± 0.21	9.08 ± 0.04	8.42 ± 0.17	8.08 ± 0.13

(a) ±2 standard deviation of the exposure rate.
(b) Sampling locations shown on Figure 4.1.1.
(c) NS = No sample; thermoluminescent dosimeter missing.